Synopsis of the OU4 Interim Measure/Interim Remedial Action Post-Closure Monitoring System (Part V)

January 1995

The Purpose of the Post Closure Monitoring Program (Part V of the Interim Measure/Interim Remedial Action document) is to monitor and confirm the performance of the engineered cover system. The post-closure monitoring system consists of three major components, including groundwater monitoring, vadose zone monitoring, and settlement/slope stability monitoring (Figure 1). All three components of the post-closure monitoring system will be implemented concurrently and are designed to provide information that will allow the identification of downward migration of water through the engineered cover and/or waste, migration of contaminated soil moisture from the vadose zone to groundwater, or upward migration of groundwater into the waste materials.

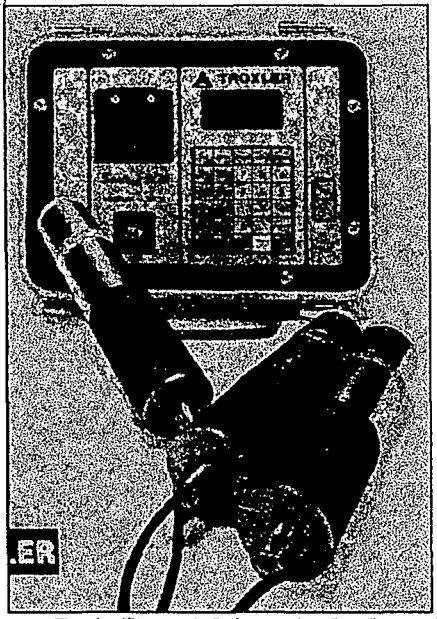
The engineered barrier is designed so that none of these conditions will occur, however the post-closure monitoring system is designed to confirm that these conditions are not occurring. In the unlikely event that one or more of these conditions is identified, then the data generated from post-closure monitoring will be used to locate the problem as well as identify options to fix the problem.

Vadose Zone Monitoring Instrumentation will be placed within the engineered barrier during its construction to monitor and confirm the performance of the engineered barrier above the water table. These vadose zone monitoring technologies will be used to evaluate the status and possible migration of soil moisture within the engineered barrier.

Four types of equipment are being used to monitor the vadose zone: *Frequency Domain Capacitance Probes (FDCs)* which determine soil moisture content in the waste material (Figure 2); *Time Domain Reflectometers (TDRs)* which determine soil moisture content in the engineered cover layers (Figure 3); *Lysimeters*, which collect soil moisture samples for laboratory analysis (Figure 4); and *Neutron Probes*, which provide a profile of moisture content in the waste materials.

The Settlement/Slope Stability Monitoring System is comprised of survey blocks and inclinometers positioned on the surface of the engineered barrier, and is designed to monitor the stability of the engineered barrier as a whole and provide early warning of potential slope failure.

Figure 2 - FDC Probes



Source: Troxler Electronic Laboratories, Inc, Research Triangle Park, NC.

The Ground Water Monitoring System includes a total of 14 monitoring wells for assessing groundwater quality around the engineered cover and will be used to detect any releases from the engineered cover to the groundwater.

Figure 1 - Placement of Monitoring Equipment

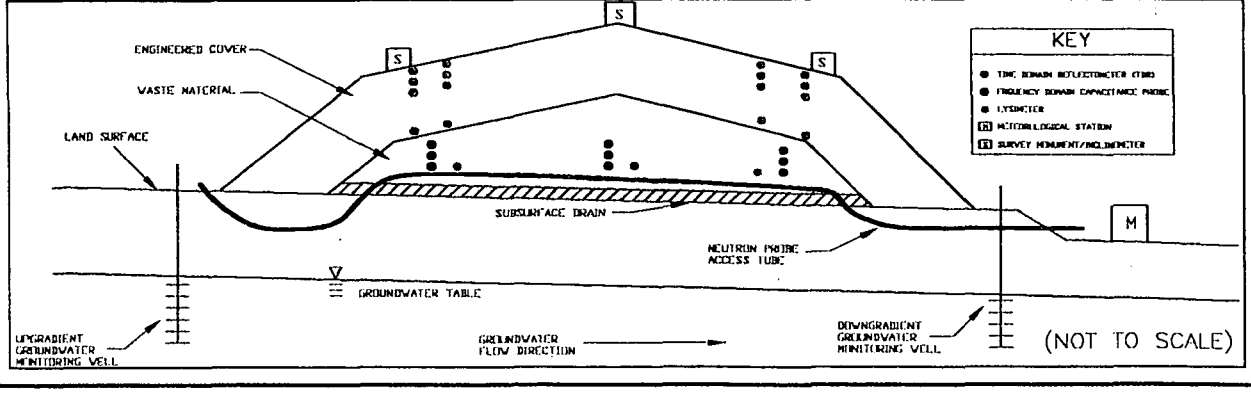
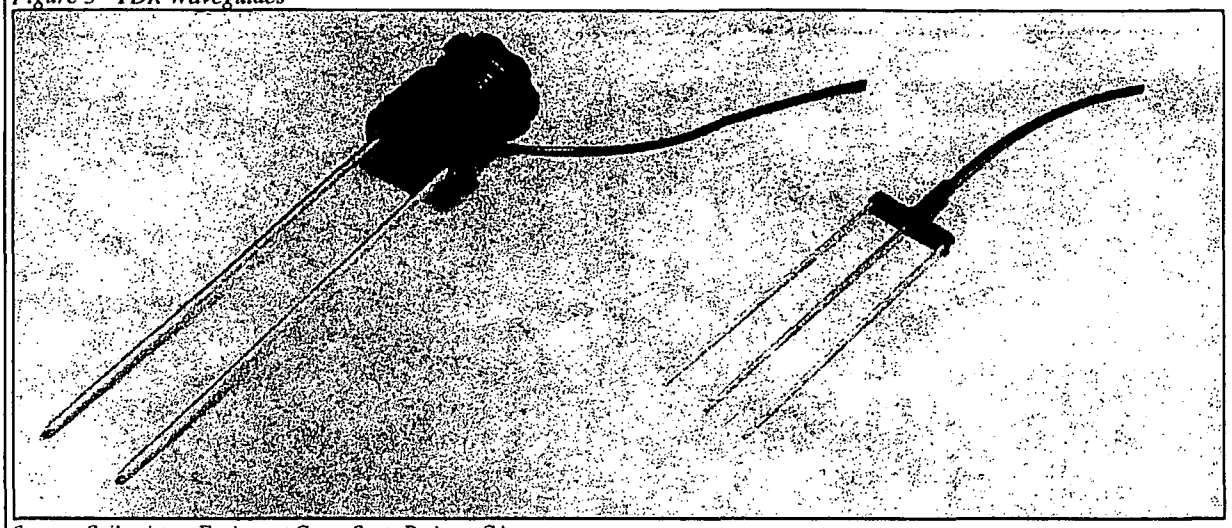


Figure 3 - TDR Waveguides

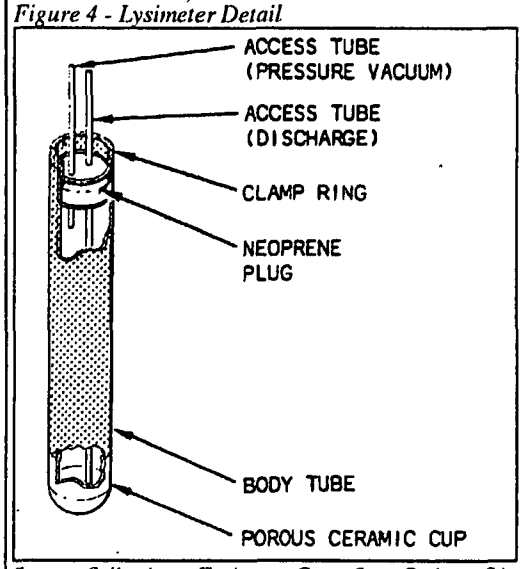


Source: Soilmoisture Equipment Corp., Santa Barbara, CA

Corrective Actions can be implemented in the unlikely event the monitoring information indicates a problem within the cover. All of the post-closure monitoring data will be collected and analyzed on a prescribed schedule using automated collection and storage methods. The data will be evaluated and reported to the appropriate regulatory agencies on a regular schedule as prescribed in the Post-Closure Permit.

The Post-Closure Permit Application Process begins after the design of the engineered cover is completed. All of the details of the monitoring program such as the frequency and duration of monitoring will be included in a post closure permit to be issued by the Colorado Department of Public Health and the Environment.

Figure 4 - Lysimeter Detail



Source: Soilmoisture Equipment Corp., Santa Barbara, CA

For More Information...

More details on the design of the monitoring system is provided in Part V of the IM/IRA document. If you have questions, please contact:

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Glossary

Vadose Zone
Unsaturated materials above the groundwater table.

Lysimeter
Lysimeters are cylindrical instruments with a porous cap on one end, allowing for a soil moisture sample to be collected and brought to the surface for analysis.

TDR
Time Domain Reflectometry instruments use fork-shaped probes to measure soil moisture content. TDRs are used in shallow soils only.

FDC
Frequency Domain Capacitance probes are cylindrical instruments which measure soil moisture content and can be used at depth.

Neutron Probe
A neutron probe measures soil moisture as it is moved through a subsurface tube, providing a soil moisture profile along the length of the tube.

Inclinometer
Inclinometers measure any tilting of the surface of the cover to indicate subsurface movement.

PRESSURE-VACUUM LYSIMETERS

Purpose

Pressure-vacuum lysimeters are designed to sample water/leachate from unsaturated pores in subsurface soil. The lysimeters are connected to the surface by tubes that apply pressure and vacuum to the suction lysimeter to induce flow into the lysimeter and to transfer collected fluids to the surface. In the event that significant moisture is determined to be present in the waste pile beneath the engineered barrier at Operable Unit 4 (through the analysis of data from the Frequency Domain Capacitance Probes and Neutron Probes), the lysimeters will be used to collect a sample of the liquid for chemical analysis.

Theory

Conventional groundwater monitoring wells cannot be used to sample water held in the vadose zone under negative pore pressures (i.e., relatively dry conditions). Under vacuum conditions of approximately 1 bar, however, a porous membrane that is part of the lysimeter can induce flow along a hydraulic gradient under unsaturated conditions and allow for the collection of water from unsaturated soil. The porous membrane through which the water flows is commonly composed of a special porous ceramic cup. Flow is induced to the surface by applying a pressure to the lysimeter with an open line at the base of the porous cup which is also open to the surface. The water is then collected at the surface and preserved for chemical analysis.

NEUTRON MODERATION MOISTURE PROBES

Purpose

Neutron moderation moisture probes were originally developed and used in agriculture to monitor soil moisture levels for the purpose of improving irrigation efficiencies. They have become the method of choice for environmental vadose zone monitoring tasks in recent years because of their accuracy and low operating costs. They are particularly cost effective where regular, frequent monitoring rounds are required from a soil zone. For the particular application at Operable Unit 4 at the Rocky Flats facility, the probe will be housed in a horizontal casing that is positioned within the waste pile. The horizontal casing allows the probe to be pulled back and forth by a cable attached to a high precision winch. Thus, soil moisture profiles are developed along the length of the casing. The practical radius of measurement varies from 6 to 24 inches from the axis of the neutron probe.

Theory

The neutron moderation moisture probe uses a fast neutron source and a thermal neutron detector to indirectly evaluate changes in soil moisture. The fast neutron source is relatively small (10 to 50 millicuries) compared with neutron-porosity loggers (250 to 5,000 millicuries), typically used in the petroleum exploration industry. The thermal neutron detector counts the fast neutrons that are emitted from the source. The fast neutrons are readily absorbed by hydrogen-containing compounds such as water. Data from the detector are statistically evaluated and compared against previous measurements to determine the soil moisture content. When used under appropriate conditions, the precision and accuracy of the neutron probe as a means of counting hydrogen is considered to be less than 1 percent of full scale, depending on the counting times employed.

TIME DOMAIN REFLECTOMETRY (TDR) PROBES

Purpose

Time Domain Reflectometry Probes are fork-shaped instruments used to determine moisture contents in soil. When installed in groups, they can be used to evaluate the direction of soil moisture movement. They are inexpensive, relative to Frequency Domain Capacitance (FDC) Probes, but have data cable length restrictions, limiting their use to shallow soil moisture measurement applications. TDRs will be used to monitor the shallow soil layers within the engineered cover at Operable Unit 4.

Theory

Time Domain Reflectometry Probes measure the velocity of a microwave pulse propagated down parallel transmission lines. The velocity of propagation is dependent on the dielectric constant of the material in contact with and surrounding the transmission lines. The higher the dielectric constant, the slower the velocity of propagation. In general, soil is composed of air, minerals and organic matter, and water. The dielectric constant, K, for these materials is :

Air	1
Mineral Particles	2 to 4
Water	80

Since the dielectric constant for water is much larger than the air and soil particles, the velocity of propagation of the microwave pulse is greatly affected by water content. Even though soil particle sizes can vary greatly, K remains virtually constant. Moreover, the variations in bulk density, temperature, and/or salt content has little or no affect upon K and therefore the accuracy of the method. This method provides a means of determining volumetric water content in the subsurface soil virtually instantaneously at a level of accuracy and precision of 2 percent.

FREQUENCY DOMAIN CAPACITANCE (FDC) PROBES

Purpose

Frequency Domain Capacitance Probes are cylindrical instruments used to determine soil moisture contents. When installed in groups, they can be used to evaluate the direction of soil moisture movement. Frequency Domain Capacitance Probes do not have the cable length restrictions associated with Time Domain Reflectometry (TDR) probes. Therefore, even though they are more expensive than TDRs, the FDCs can be used for deep soil moisture measurement applications. The FDCs will be used to monitor the waste materials beneath the engineered cover at Operable Unit 4.

Theory

Frequency Domain Capacitance Probes measure the capacitance of an electrode system based on the dielectric constant of the soil surrounding the probe. The capacitor in the FDC forms part of the feedback loop of a high frequency oscillator. In general, soil is composed of air, minerals and organic matter, and water. The dielectric constant, K, for these materials is:

Air	1
Mineral Particles	2 to 4
Water	80

Since the dielectric constant for water is much larger than the air and soil particles, the dielectric constant measured by the FDC Probe is directly proportional to the water content. Even though soil particle sizes can vary greatly, K remains virtually constant. Moreover, the variations in bulk density, temperature, and/or salt content has little or no effect upon K and therefore the accuracy of the method. Accuracy of capacitance probes is within 2 percent of the actual water content.